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Wellbeing and sustainable development: a multi-indicator approach

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Abstract

We propose an innovative approach to monitor progress in wellbeing and sustainable development in the context of a multi-indicator situation. We analyze improvement trajectories over two time periods for nine European countries, showing the differences between consistent and unambiguous improvement and non comparable changes. We find that improvement has been widespread in the socio-economic domain and much less so in the environmental domain.

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1. Introduction

Since 1972, governments around the world have signed a number of important joint declarations on sustainable development (among which: the Stockholm Declaration in 1972, the Rio Declaration on Environment and Development in 1992 and the Johannesburg Declaration in 2002) and they have adopted some important policy documents (i.e. Agenda 21 in Rio de Janeiro 1992, the Action Plan of Johannesburg 2002).

These declarations and documents were supposed to lead the way for the redefinition of national policies on sustainable development: a United Nation's Commission on Sustainable Development was established shortly after the Rio 1992 Conference to monitor the implementation of Agenda 21 and the Rio Declaration. The commission proposed a set of Indicators of Sustainable Development (CSD indicators), published in 1995 and subsequently

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revised before the 2002 World Summit in Johannesburg. At that stage, the indicators provided countries with a sample set "to track progress toward nationally-defined goals" (United Nations 2007); in other words there was no requirement for countries to adopt all (or any) of the indicators or to coordinate their priorities. That arrangement preserved the possibility of reaching a (vague) international agreement in principle on sustainable development, whereas specific commitments and commensurable indicators of progress could not be agreed.

A further step was possible when all member countries of the United Nations agreed to commit to the 8 "Millennium Development Goals" (MDG) after the Millennium Summit of New York City in 2000, a process which was only in part connected with the Rio Declaration, but nevertheless indicated specific targets for sustainable development and a set of 48 indicators (MDG indicators) of progress (increased to 58 since 2007) to be collected with a global effort. In spite of being agreed upon by all countries in the UN system, MDG raised considerable criticism among scholars because of a supposed lack of analysis and justification behind the chosen objectives and lack of appropriate measures for some of the goals.

In 2012, the Rio+20 conference, after two years of heated negotiations, produced a mostly programmatic document, titled "The Future We Want" launching several international and national processes on issues considered crucial for the future of the Planet. One of the most important results achieved at Rio+20 was an indication to proceed to the redefinition of the current policies on sustainable development. Part of that effort will be addressed at identifying a set of targets called Sustainable Development Goals, based on the MDG and part of an effort of convergence towards a unified development agenda. Progress towards the Sustainable Development Goals will be monitored with an appropriate set of indicators (SDG indicators) that will arguably be a re-elaboration of the CSD indicators and the MDG indicators.

While before 2012 MDG indicators and CSD indicators partly overlapped but had a different purpose (United Nations 2007), now indicators of sustainability from both sources can be considered part of the same policy effort. The SDG indicators and the corresponding datasets are not yet available at the time of writing this paper, and the process of defining a global definition of progress in sustainability is ongoing.

In this work, we analyze a dataset of indicators built for the MDG that have stronger ties with the sustainable development domain and the CSD indicators. We expect them to be a credible example of the future SDG indicators. We study, for a number of countries, the evolution over time of these indicators, in the framework of a multi-indicator methodology. We propose innovative parameters to compare different countries and to monitor and rank overall progress of each country towards a common set of objectives. In the light of the results, we comment that even a much smaller number of indicators than those expected to monitor the SDG is likely to make the notion of overall progress in sustainability elusive.

2. Data and Methods

2.1. Overall progress in sustainability: data and indicators

The database of the MDG indicators is freely available online (mdgs.un.org). A systematic review of the overlaps between the MDG indicators and the CSD indicators was made in 2007 (United Nations 2007) and while Rio+20 is supposed to produce changes in such scheme and make the overlap much larger, at the time of writing this paper the process of convergence is still ongoing. Since MDG indicator values are available for a large number of countries in relatively long time series, whereas no equivalent database for Sustainable Development Goals exists, we identified 11 MDG indicators that are most similar to sustainable development indicators:

1. ID 751: Carbon dioxide emissions (CO2), metric tons of CO2 per capita (CDIAC)
2. ID 567: Proportion of land area covered by forest, percentage
3. ID 768: Proportion of total water resources used, percentage
4. ID 784: Terrestrial areas protected to total surface area, percentage
5. ID 648: Energy use (kg oil equivalent) per $1,000 GDP (Constant 2005 PPP $)
6. ID 665: Proportion of the population using improved drinking water sources, total
7. ID 668: Proportion of the population using improved sanitation facilities, total

8. ID 561: Children under five mortality rate per 1,000 live births
9. ID 722: Share of women in wage employment in the non-agricultural sector
10. ID 755: Fixed-telephone subscriptions per 100 inhabitants
11. ID 756: Mobile-cellular subscriptions per 100 inhabitants

The list above is not meant to be comprehensive of all the dimensions of sustainability. In fact, our goal is to propose a method to track the overall longitudinal and cross-sectional progress on multiple indicators, and this will ultimately be shown to be meaningful only with a relatively small number of indicators. The results will also highlight the serious shortcomings of methods, like composite indices, that are frequently used for the same purpose. As limited as the list above certainly is, it will prove to be too large to support a single measure of overall progress.

With all these things being considered, the inclusion of a few other indicators was nonetheless carefully pondered, as some dimensions of sustainable development are certainly not represented in the list. Environmental indicators that build on experience of the MDGs and are likely to be included in the SDG indicators are available in good numbers but are affected by large amounts of missing data and cross-country discrepancies in measurement methods. The issue is particularly relevant because of the relatively long time series required to follow the entire process starting before Rio 1992. Additional social and economic indicators that are likely future SDG indicators, were also considered, particularly those concerning education and poverty. In many cases, however, such indicators originating from the MDGs have little or no variability in developed countries (as the countries analyzed in this work, see section 2.3 for the list) and sometimes they are not collected at all. Additional indicators are obviously available from sources other than the MDG indicators dataset that, however, we prefer not to mix with a credible subset of the future SDG dataset in the main section of our work to remain consistent with our sources.

Therefore, in order to provide an example with an exhaustive dataset, we will analyze a UN dataset on greenhouse gas emissions in the latter part of section 3, following the analysis based on the indicators above.

2.2. Partial Order Scalogram Analysis by Coordinates (POSAC)

As a convenient tool to analyze progress in the context of a multi-dimensional issue, we identified POSAC. POSAC is a non-metric technique for exploratory data analysis. It is used when order relations between statistical units are considered a crucial quality of the information available, and such information is represented by a multivariate dataset of ranked variables. While statistical units can be ranked according to each single ranked variable, rankings can be inconsistent between two or more variables. POSAC reduces the dimensionality of the dataset so that it can be easily represented in an (x, y) Cartesian coordinate space (Shye 1985; Brüggemann and Patil 2011), at the same time maximizing the preservation of partial orderings. Each statistical unit a (x_a, y_a) is unambiguously worse of all other units n (x_n, y_n) for which ($x_a < x_n$ and $y_a \leq y_n$) or ($x_a \leq x_n$ and $y_a < y_n$); we can say that a (x_a, y_a) is unambiguously better than any n (x_n, y_n) for which ($x_a > x_n$ and $y_a \geq y_n$) or ($x_a \geq x_n$ or $y_a > y_n$); in all other cases, a is not comparable with n. As a consequence, the top right corner of the Cartesian space represents the best theoretical outcome (top rank in all variables) and the bottom left corner represents the worst theoretical outcome (bottom rank in all variables). The line joining them (called Joint Axis) is the main dimension of the resulting two-dimensional space. Being oriented so that $y = x$, the interpretation of the Joint Axis is straightforward. As we move along it, growing values of the coordinates indicate strict improvement in all rankings at the same time. The line joining the two remaining corners, which is the secondary dimension, is called Lateral Axis. Moving along it can be interpreted as having some rankings that improve while others deteriorate. Consequently, determining which variables are directly or inversely correlated to the Lateral Axis explains why certain units of the dataset are represented closer to the bottom right or to the top left corner.

2.3. Trajectories and progress

Our use of POSAC in this context is based on the following considerations:

- Progress of a country in sustainability can be defined as unambiguous improvement in all sustainability indicators over time.

- Size of progress must be somewhat relativized because overall improvements, as well as improvements in specific indicators, are influenced by factors that are beyond reasonable policy control (e.g. forest coverage or proportion of water resources used in desert regions; CO2 emissions and energy use in economies based on industrial production compared to those based on agriculture or tourism, etc.).
- The relativization cannot be country-specific (meaning that each country has a target for each indicator) both because such targets are rarely identified and because, when they are, there is no guarantee that they are based on comparable parameters across countries.
- The size of progress can, however, be defined in terms of getting closer to the best reasonable outcome, i.e. to the best outcome scored by a relatively similar country in the time period.

We operationalized these points as follows.

First, we focused the analysis on nine European countries that can be thought to have reasonably similar environmental and developmental contexts (Belgium, France, Germany, Hungary, Italy, Netherlands, Portugal, Spain, United Kingdom). Each country is represented in the POSAC analysis with three records, one for year 1990, one for year 2000 and one for year 2010, so that the total amount of records is (3 years by 9 countries) 27.

The full dataset is, consequently, a 27×11 matrix (with the 11 columns representing the 11 MDG indicators). The scores in each column are ranked 1-27, with rank 27 being the best combination of year, country and score and 1 being the worst combination. In other words, each country appears three times and its progress is relative to itself in the past and to other similar countries.

We estimated POSAC based on all the variables above and with different combinations of variables. As expected, most combinations were not particularly effective when represented in a two-dimensional space: increasing the number of variables, in fact, increases the share of statistical units that are incomparable with each other. As a matter of fact, even with this relatively small dataset, overall progress is hardly identifiable if it is based on more than five or six different dimensions of sustainability. Ultimately, we chose two different groups of four inter-correlated variables to estimate two different POSACs, based on the matrix of Spearman correlations reported below. To facilitate interpretation, coefficients above 0.4 are marked in bold.

Table 1. Spearman Correlation Matrix of the selected sustainable development indicators (bolded correlations are significant at a 0.05 level).

Variable	Group	751	567	768	784	648	665	668	561	722	755	756
751	2	1.000										
567	2	**0.491**	1.000									
768	2	**0.400**	-0.314	1.000								
784		-0.181	0.311	-0.173	1.000							
648	1 and 2	**0.509**	**0.626**	-0.022	0.220	1.000						
665		**-0.455**	-0.126	**-0.488**	**0.446**	0.051	1.000					
668		-0.332	**-0.398**	-0.249	0.188	-0.275	**0.692**	1.000				
561	1	-0.095	0.272	-0.209	**0.623**	**0.420**	**0.527**	0.278	1.000			
722	1	0.239	-0.004	**0.435**	**0.479**	0.101	0.074	0.095	**0.534**	1.000		
755		**-0.403**	-0.118	-0.100	**0.463**	-0.023	**0.516**	0.296	**0.535**	0.345	1.000	
756	1	0.048	0.106	0.073	**0.584**	**0.463**	**0.393**	0.208	**0.851**	**0.667**	0.324	1.000

We denote as “Group 1” the group of variables 648, 561, 722 and 756. Quite obviously, this group includes socio-economic indicators and development indicators. They represent the socio-economic dimension of sustainability which is likely to translate into the future SDG indicators because of the overarching goal of the international institutions to eradicate poverty and putting people at the centre of sustainable development (https://sustainabledevelopment.un.org/sdgproposal).

“Group 2” consists of variables 751, 567, 768, 648 and is focused on classic environmental indicators, with emphasis on consumption of non-renewable resources.

3. Results

Figure 1 represents the POSAC estimated for Group 1 variables. Some trajectories are highlighted to show cases where we can see overall improvement, marked by higher values both of the *x* and the *y* coordinates (as is the case with the Netherlands between 1990 and 2000) and cases where changes are incomparable as one coordinate grows and the other decreases (like in the case of Spain between 1990 and 2000).

2010 France, United Kingdom and Portugal lead the way in socio-economic wellbeing, each at the top of three largely incomparable trajectories. Most countries in the time period have an unambiguous improvement according to these indicators (Hungary, Spain and Portugal experience ambiguous changes between 1990 and 2000); all of them improve at least between 2000 and 2010. Interestingly, South European countries share a common development trajectory, on the right side of the figure, characterized by a less energy-intensive model of development but also less gender parity. In fact, the two variables concerning energy intensity and women in wage employment are strongly correlated with the Lateral Axis and their correlation coefficients have opposite signs.

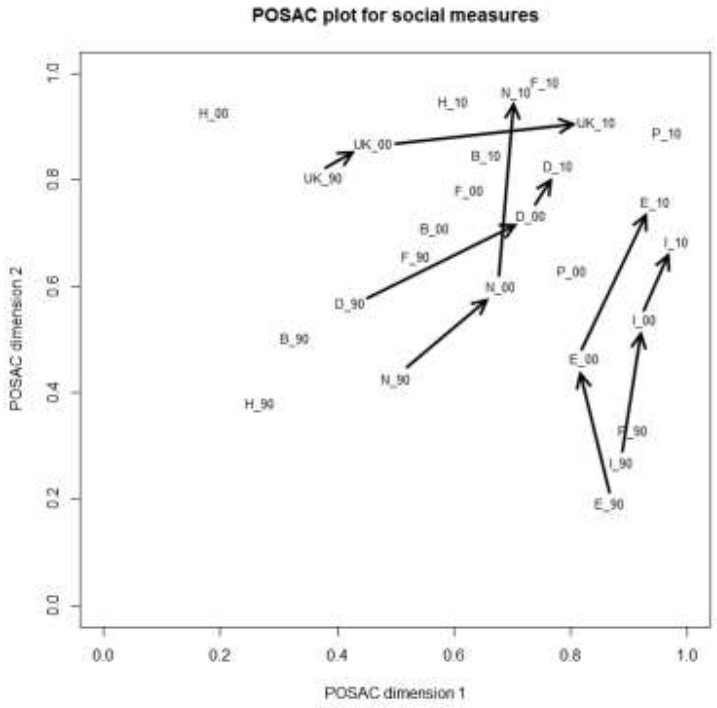

Figure 1: POSAC with group 1 indicators

Figure 2 represents the POSAC estimated for Group 2 variables. Portugal dominates the ranking in environmental indicators in all years in spite of regressing between 1990 and 2000. Italy 2010 and Germany 2010 also obtain remarkable scores. Countries on the right hand like Hungary, Netherlands and the United Kingdom have their own trajectory of environmental sustainability, which is relatively weaker in forest coverage and energy consumption but stronger in more unused water resources. Again, this can be inferred by the correlation coefficients between these variables and the Lateral Axis. In the case of environmental variables, only two countries show an unambiguous, consistent improvement over time: Germany and Hungary. For many countries like Italy, France or Spain, it is even impossible to find unequivocal improvement between 2000 and 2010. Another detail that should be noticed is that many of the most evident socio-economic improvements in Figure 1 (Netherlands 1990-2000;

Belgium 1990-2000; France 2000-2010; Spain 2000-2010) are associated with very lackluster environmental performances in Figure 2.

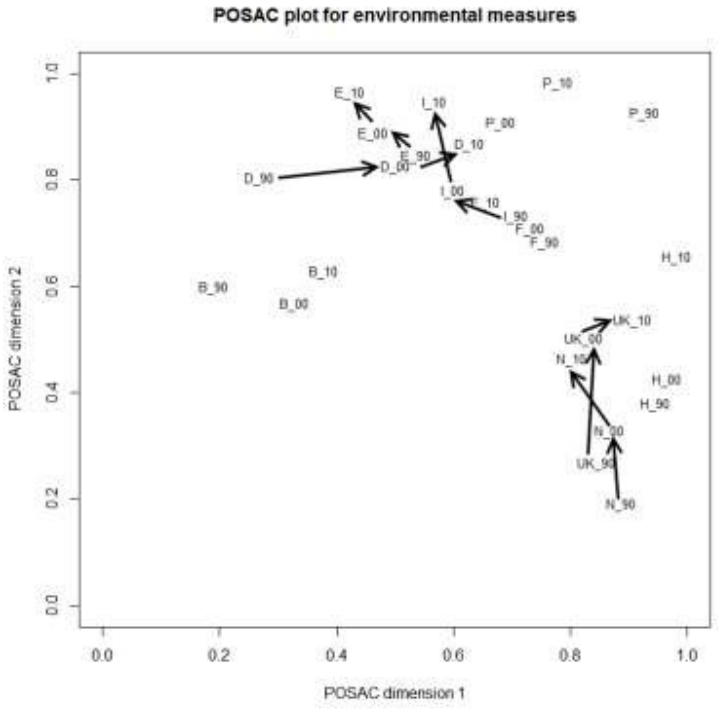

Figure 2:POSAC with Group 2 indicators

With the mere intent of providing an example of an environmental POSAC based on an exhaustive dataset, in Figure 3 we show the POSAC of the same nine countries by three years, obtained from six indicators of greenhouse gas emissions *per capita* (CH4, CO, N2O, NMVOC, NOX, SO2) collected by the UN environmental agency UNEP. We are not going to provide much comment on it as the specific theme of emissions goes beyond the scope of our work, even if the figure can be read as an indication that poor performances in environmental indicators in Figure 2 do not depend on lack of improvements on CO2 emissions but, rather, on the other indicators. As a matter of fact, Figure 3 shows mostly ambiguous changes between 1990 and 2000 and overall progress in most countries between 2000 and 2010. The internal consistency and exhaustiveness of this POSAC does not depend on the number of variables (which is quite high anyway) but on the fact that they conjointly represent all the main dimensions of the issue. The POSAC presents a number of incomparable situations, but overall progress is still visible in spite of the use of many variables because of the very tight relation between them and the resulting consistency of the dataset.

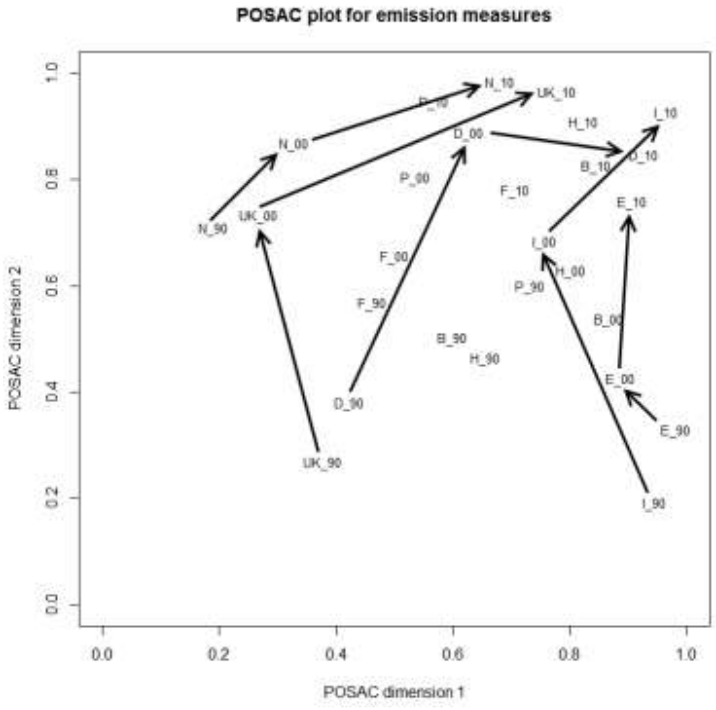

Figure 3:POSAC with greenhouse gas emission indicators

4. Conclusions

With the use of POSAC and the identification of progress trajectories, we have shown a method to analyze improvements in sustainability in the presence of multiple indicators. We found a generalized improvement in socio-economic indicators and much less consistent outcomes in strictly environmental indicators, particularly those not related to emissions. In both cases, the number of incomparable statistical units is quite high. In the socio-economic sphere, countries can mostly be compared with themselves at different times (they are unequivocally improving) but comparison between countries is rarely possible. This means that, in the last twenty-five years, in spite of generalized improvements, their strengths and weaknesses compared to others tend to persist.

In the environmental sphere, overall progress is very rare and countries are rarely comparable both with others and with themselves. In some cases, like it happened with the socioeconomic indicators, this depends on the fact that relative strengths and weaknesses tend to persist over time but, in Figure 2, when a country changes over time, its improvements in some areas seem to be made at the expense of other areas. A good example is that of France, Italy and Spain: in the last 25 years, all three have improved their score in forest coverage and intensity of energy use, but now they are consuming more water resources.

The results illustrate that overall progress in sustainability quickly becomes elusive, when such notion is based on too many dimensions. This can be inferred from Figure 1 and 2: social sustainability and environmental sustainability are already affected by much incomparability in spite of being relatively narrow concepts. Combining the two would dramatically increase incomparability and overall progress in a dataset of dozens of indicators would almost surely be exceptionally unlikely.

In our interpretation, these results allow to make three claims. The fist is that, as overall progress in sustainability is highly unlikely if measured against too many unrelated parameters, therefore, methods that forcefully measure overall progress like composite indices, can be very misleading and depend on (frequently opaque) assumptions about the importance of each parameter and on the resulting concealment of incomparability. What they measure is not, ultimately, overall progress but progress in parameters that they consider more relevant.

The second claim is that, even if methods like the one used here can provide rankings of progress without concealing incomparability, if our intent is to make multidimensional overall progress commensurable, the number of dimensions should be kept at a maximum of ten or less. Comprehensive datasets like those currently studied for the SDG indicators, without a transparent hierarchical structure of importance in the indicators (based on normative as well as qualitative and quantitative criteria) are going to be useless for the sake of tracking overall progress.

Finally, the third claim is that, while seeing little overall progress in sustainability in the last 25 years can depend, to a degree, on the lack of consistent multidimensional effort in all countries, it seems unlikely that this is the main reason. Actually, the results we got look very much like those that should be expected if any couple of our parameters were linked by a trade-off relation, so that improving one is likely to lead to a deterioration of the other. For example, there is no way to tell, from our data, that improving social sustainability has a price in terms of environmental sustainability, but it surely is in the realm of possibility and the results do nothing to disprove this. Under this interpretation, the use of partial order methods like POSAC reminds of the concept of Pareto optimality, with a country's scores in different indicators representing its particular policy mix, and the incomparability between countries, or for one country at different times, seems related to the utility-possibility frontier and movements along it. This relation seems a promising field for further research.

In any case, these results should be seen as an opportunity to have a better analytic point of view over the results of sustainability policies. They should also be interpreted as a warning: different dimensions of sustainability resist attempts to collapse them in synthetic indicators and possibly show the signs of tradeoffs at least at the time scale analyzed here.

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